AN INVESTIGATION INTO THE SPATIAL DISTRIBUTION OF STREAMWATER CHEMISTRY ALONG THE GREAT MIAMI RIVER AND ROLE OF LAND USE TYPE

Senior Thesis
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Table of Contents

Abstract

Previous studies have shown that the Great Miami River watershed is a top contributor to nutrient load into the Mississippi River and ultimately to the Gulf of Mexico. High nutrient content corresponds to higher algal bloom rates, which can be devastating to environments and economies. Streamwater chemistry in the watershed has been studied extensively previously, however, a geospatial dataset of the scale studied here has never been collected before, which can provide insight into how the streamwater chemistry changes spatially. The land use type of the upper Great Miami River is predominantly agricultural, with 75.3% of the total upper watershed being agricultural (68.36% cultivated cropland, 6.93% pasture/hay). The land type throughout the area is extremely uniform, where land type changes relative to discharge area are minimal. On May 16th 2017, water samples were collected along the Great Miami River (upper) watershed (Figure 1.), and analyzed for major cation, anion, and nutrient concentrations in the following weeks. The null hypothesis was to see if leeching of the agriculture in the area would overload the stream, creating uniform streamwater chemistry across the watershed area. Agriculture accounts for over 68% of the total upstream land use type above the pour point. Post analysis, the data collected have led to the conclusion that the null hypothesis cannot be rejected.

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I thank Dr. Anne Carey for everything. She has been extremely patient with me as I wrote and researched. She always dropped everything immediately and gave me full attention whenever I needed her help, and was always there to talk to when I was in need. I need to thank Dr. Sue Welch for conducting the sample runs, and categorizing the data neatly onto an excel sheet for me. She also assisted and gave me her full attention when I came by to visit and I am very grateful. I also thank all of my other undergraduate professors for pushing me to become the best student possible. I apologize and thank everyone for understanding as I strive to be a better student and researcher. A special thanks to Dr. Alycia Stigall for her captivating lectures on Earth Sciences which made me fall in love with the subject, and prompted my decision to declare a major in this field.

I also need to thank Dr. Karen Royce for her excellent guidance throughout the years, and the School of Earth Sciences in general for providing an excellent environment for growth in education and success.

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INTRODUCTION

The upper Miami River watershed (Figure 1) should be studied because it has been shown that this basin is a large contributor of nutrients to many bodies of water all the way to the Gulf of Mexico (Goolsby et al., 1999). These nutrient loads, namely of phosphorous and nitrogen, pose persistent problems of harmful blue algae blooms and hypoxia in environments. In effort to reduce and discover the origin of said nutrient concentrations, it is first essential to collect a geospatial dataset. Collection of water throughout the watershed can give insight into the role of lithologies and land use. The goals of this study were to provide a geospatial dataset of the Upper Miami river streamwater chemistry and to relate the streamwater chemistry to the land use of the upstream drainage area for each sample. A USGS ArcGIS dataset, National Land Cover Database (NLCD), was used for determining land use type throughout the watershed. The most recent land use data, 2011, was used. Nine water samples were collected along the Great Miami River (Figure 1), and two more samples were collected (one each) on the two major tributaries (Stillwater and Mad River) that merge near the pour point of the watershed. Chromatography and a nutrient analyzer were used to determine concentrations.

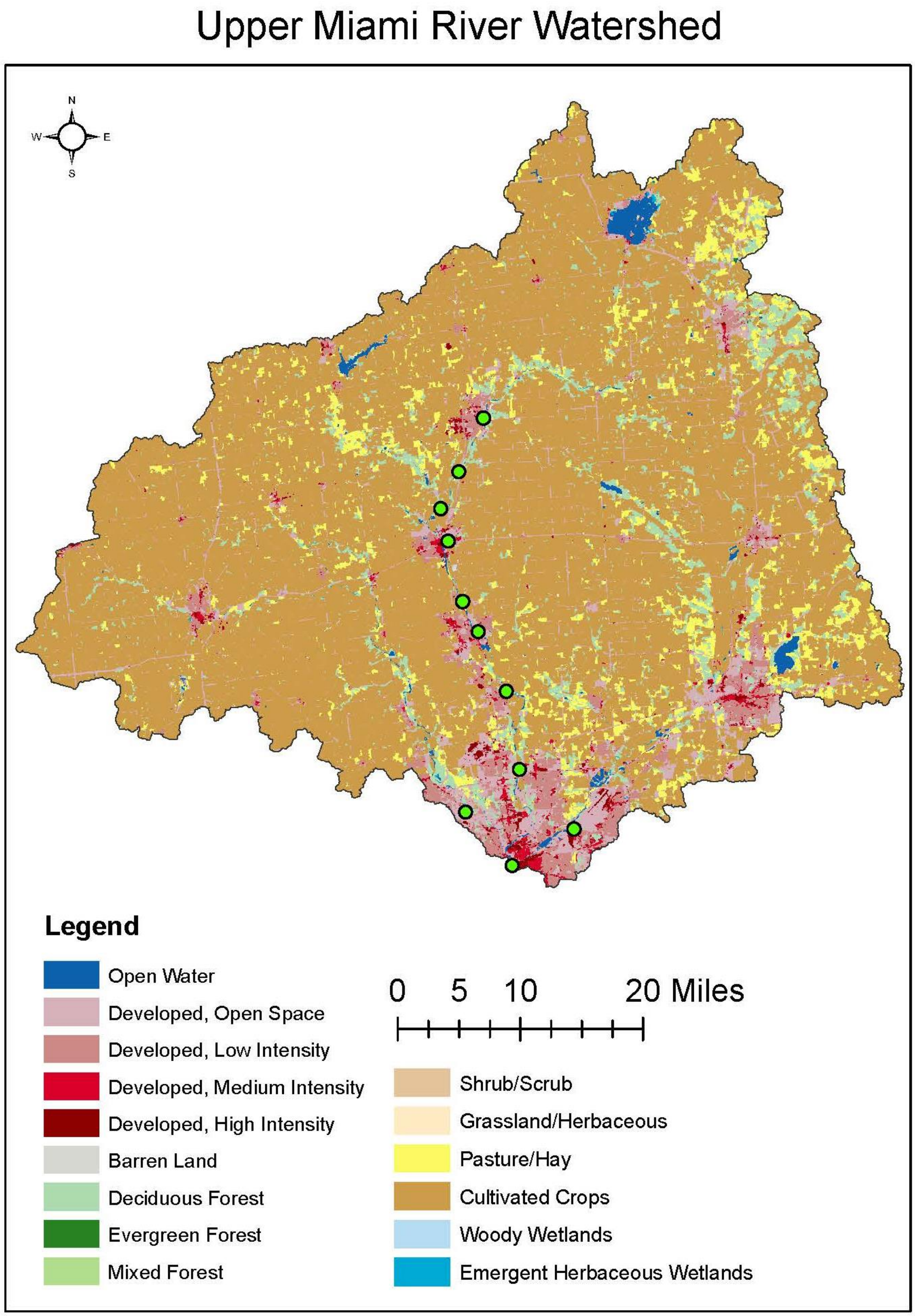

Figure 1. Map of the study area created in ArcGIS. Green dots represent sample locations. Land use data provided by the most recent USGS National Land Cover Database (Homer, C.G). Watershed area data provided by (USDA).

GEOLOGIC SETTING

Geology

The geologic setting of the upper Great Miami River watershed is predominately dolostone, limestone, and shale; which has a layer of glacial till sitting on top of the bedrock. (USGS). The common soil series in the upper Great Miami River watershed area are mostly Miamian-kokomo-Eldean, with minor amounts of Blout-Pewamo-Glynwood and Hoytville-Nappanee-Paulding-Toledo. All soils series have been glaciated. (ODNR)

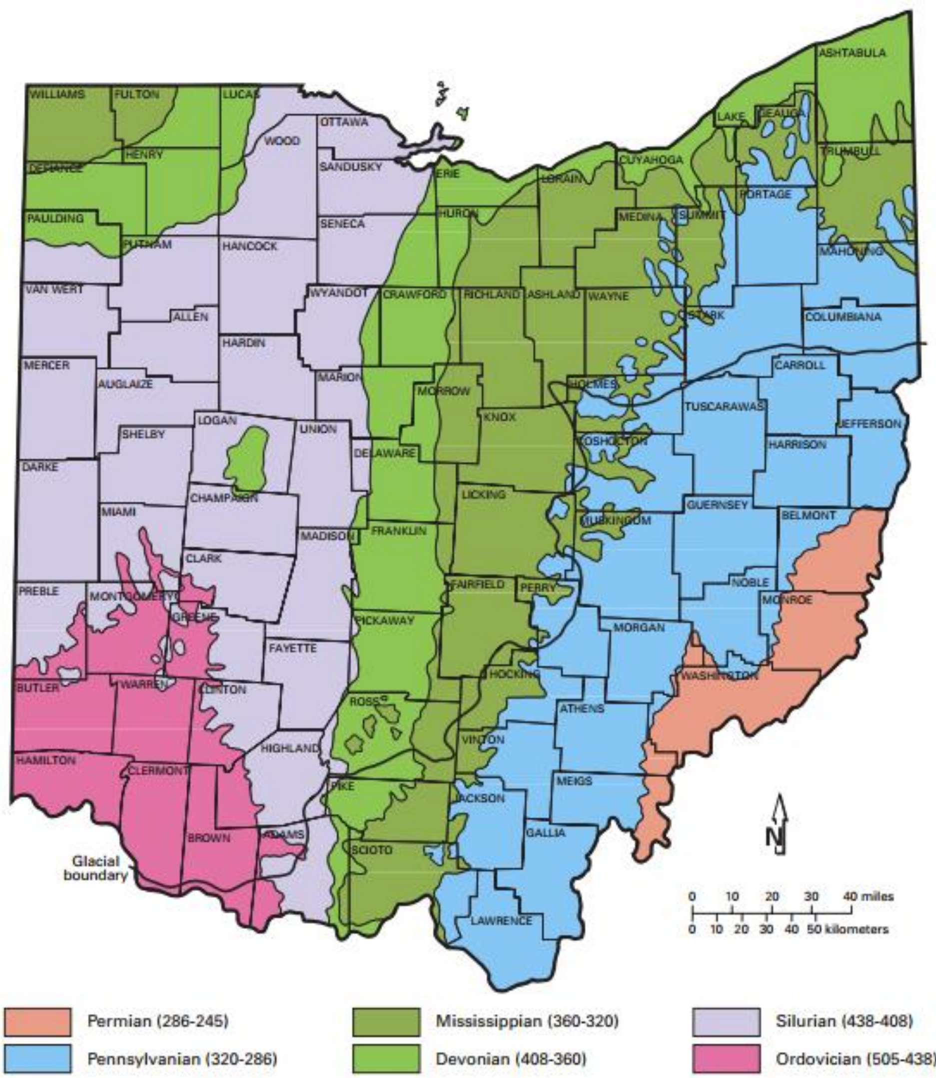

Figure 2 Watershed lies in south western Ohio. All samples were collected in Shelby, Miami, and Montgomery counties. Rock layer map obtained from Coogan (1996).

METHODS

Sampling methodology

Water samples were collected, by hand, during the day, facing upstream, using Nalgene 0.5L HDPE bottles. Bottles were rinsed a minimum of 4 times using the stream water before collection. The water used to wash was then emptied downstream. Two of the rinsings were to the brim of the bottle, the other two were filled ~ 1/2-3/4 full then vigorously shaken, and emptied downstream. The cap of the bottle was also submerged while the bottles were filling. All samples were collected in an area of higher velocity stream flow; no samples were taken directly at the edge of the river or in stagnant eddy pools. Bottles were then placed into a cooler containing icepacks to keep the samples cool and out of the sunlight. The pH of the water was determined by using a pH meter on site after collecting a sample of the water from the same location as the sample was collected form. The water to measure pH was scooped up into a small plastic Nalgene cup. Once all samples had been collected, they were placed into a refrigerator overnight until transported to the lab for filtration and analysis. The samples were also transported in cooler to water analysis location. MRW-09 and MRW-11 samples were both collected at the two major tributaries leading into the upper Great MRW near the pour point. MRW-09 was collected at Stillwater River (west of the great Miami River), and MRW-11 was collected in Mad River (east of the great Miami River). All other samples were directly sampled along the upper Great MRW. MRW-10 was taken at the pour point of the upper Great MRW in downtown Dayton. Samples were numbered in collection order, starting at MRW-01 in Sidney Ohio, and sequentially downstream (Figure 1).

Water analysis

Cations were analyzed using a Dionex DX120 ion chromatography and anions were determined using a Dionex-ICS 1200 following the methods of Welch et al. (2010). Nutrient analyses ware performed by using a Skalar SAN^{++} nutrient analyzer with methods provided by the manufacturer. A standard used to calibrate the Skalar overloaded the sensors when running for N NO_3 and Si concentrations, so diluted samples (MRW-01D), were diluted down to 1/10 their natural concentration. Duplicates of MRW-03 and MRW-08 were run to check for precision. Two duplicate samples were run on all tests, with a minimum of five known standards to check for precision and accuracy. The duplicates and standards run never resulted in greater than a 5% difference, supporting the accuracy and precision of the data.

Data interpretation

The area upstream of a sampling location was calculated by summarizing the data table in ArcGIS based on the land type GEOCODE. For example, summed all polygons within a watershed area that had geocode '11' where '11' represents open water. Percent of area is the total area upstream, that is classified as a particular land use type, according to the USGS NLCD 2011 data (Homer, C.G.) and definition of categorization of land use type. Calculated by the total area in square miles of a particular land type divided by the total upstream, discharge area. Total upstream area, was calculated by summing the total area of all upstream watershed polygons from a pour point. Variance and standard deviation were calculated of the percent change in total upstream land type as samples were collected in the downstream direction. Only data points that fell near a pour point within the watershed were used in this way to accurately have a known total upstream area and land use type. To use the data points that fell between pour points in this way, one would have to break down the smaller watershed areas even further, which is too small scale for this study. Variance was calculated using the excel function VAR.P, and standard deviation was calculated by taking the square root of variance. This ultimately showed the land type change of upstream watershed area is negligible from upstream down the river.

Table 1. Percent land use type for total area in Upper Great Miami Watershed

Land Use Type	Open water	Developed, open space	Developed, Low Intensity	Developed, Medium Intensity	Developed, high intensity
% of total upper watershed area	0.01	0.079	0.03734	0.0125	0.0056
Land Use Type	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub
% of total upper watershed area	0.0005866	0.08479	0.000736	0.00	0.0000112
Land Use Type	Grasslands/Herbaceous	Pasture/Hay	Cultivated Crops	Wetlands	
% of total upper watershed area	0.0129	0.0693	0.6836	0.0025	

Sum of all land use type = 0.99895

RESULTS

Concentration of major elements

Table 2. Anion concentrations of samples collected along the Upper Great Miami River

	F mg/l	Cl mg/l	est. N NO2 mg/l	Br mg/L	NO3 N mg/l	SO4 mg/l	PO4 P mg/l
MRW17-01	0.28	26.0	0.010	0.019	3.80	33.7	0.011
MRW17-01 replica	0.28	26.0	0.011	0.019	3.80	33.6	0.012
MRW17-02	0.29	27.9	0.008	0.019	3.39	37.3	0.028
MRW17-03	0.07	28.1	0.008	0.020	3.31	37.7	0.034
MRW17-04	0.27	27.3	0.010	0.020	3.76	38.6	0.040
MRW17-05	0.28	32.0	0.007	0.022	3.96	39.5	0.051
MRW17-06	0.27	31.1	0.016	0.022	4.05	38.5	0.046
MRW17-07	0.25	31.4	0.010	0.022	3.88	35.7	0.054
MRW17-08	0.26	32.6	0.009	0.024	4.07	35.6	0.048
MRW17-09	0.23	33.8	0.005	0.022	5.25	35.0	0.024
MRW17-10	0.24	42.4	0.011	0.025	2.53	38.2	0.044
MRW17-10 replicate	0.24	42.5	0.011	0.026	2.53	38.3	0.042
MRW17-11	0.23	39.2	0.014	0.026	2.68	38.4	0.052

Anion concentrations appear to remain consistent throughout the watershed (Table 1). The overall decline of N NO_3 can be attributed to a severe shift in land type at the pour point, being predominantly urbanized for a good stretch before the sample point. In general, there is an ever so slight net gain of F, Cl, N NO_2, Br, SO_4, and PO_4 as one moves downstream.

Table 3. Cation concentrations of samples collected along the Upper Great Miami River

Column1	Li mg/l	Na mg/l	K mg/l	Mg mg/l	Ca mg/l
MRW17-01	0.004	14.08	2.61	29.19	78.36
MRW17-01 replica	0.003	14.24	2.60	29.22	78.63
MRW17-02	0.004	15.94	2.92	28.74	78.95
MRW17-03	0.004	16.39	2.98	28.53	78.92
MRW17-04	0.004	18.07	3.30	28.86	79.34
MRW17-05	0.004	19.68	3.36	28.85	80.19
MRW17-06	0.004	18.56	3.28	28.83	79.60
MRW17-07	0.004	20.55	3.34	28.92	79.95
MRW17-08	0.003	19.63	3.12	29.62	81.64
MRW17-09	0.003	18.51	2.55	33.81	90.93
MRW17-10	0.004	25.08	2.89	36.74	79.37
MRW17-10 replicate	0.004	25.08	2.89	36.75	79.73
MRW17-11	0.005	23.00	2.89	36.53	91.77

Li and Ca remain consistent throughout the river, changing by little (Table 2). Curiously, the two main tributaries sampled have a higher concentration of Ca, being 90.93 mg/l at Stillwater River, and 91.77 at Mad River. There is also a slight relationship of increased Na and Mg as one samples downstream. Potassium increases from MRW17-01 to MRW17-05, then steadily decreases as the land type becomes more urbanized in the immediate vicinity of the river.

Table 4. Nutrient concentrations in ppb

Sample	PO4 ppb average	NH3 ppb average	N NO3 ppb average	Si ppb average
MRW-01	10.35	3.49	3,730	2,116
MRW-02	29.25	3.04	3,287	2,259
MRW-03	30.15	3.00	3,375	2,545
MRW-04	41.20	3.06	3,871	2,735
MRW-05	53.55	3.53	3,918	2,818
MRW-06	45.75	3.48	4,056	2,669
MRW-07	61.85	3.75	4,166	2,798
MRW-08	55.95	3.23	4,122	2,924
MRW-09	47.55	3.06	5,026	2,781
MRW-10	59.65	2.21	2,800	3,269
MRW-11	73.00	3.25	2,958	3,515

This suggests PO_4 concentrations tend to increase downstream. NH_3 concentrations remain relatively stable and uniform throughout the river. N NO_3 increases downstream, then appears to encounter a sink when it hits urbanized Dayton, dropping down to 2,800 ppb at the pour point, from 4,122 ppb from the next data point upstream. Si steadily increases as the upstream area increases.

Discussion

Cl and Br have been shown to shift in concentration seasonally, and are inferred to be linked to change in agricultural activity and addition of salt on roads to melt ice (Starr and Fortner, 2014). No relationship in Cl concentrations was been found throughout 1996–2015, using data from the National Center for Water Quality Research, only possible inflections during years of heavy snow, correlating to more salt added to roads to melt snow (Shaffer et al., 2016). Previous research has also concluded that most historical data is inconsistent, but correlation of higher concentrations of Cl amounts and anthropogenic activities has directly been observed. Na has more complex geochemistry and is harder to measure concentrations geospatially (Dailey et al., 2014) and long term datasets have shown increased amounts of Cl and Br is due directly because of human activities. Higher concentrations of Na have also been inferred to be a direct result of de-icing salt applications in the winter.

The Mad River tributary has the lowest amount of upstream agricultural land use, and the largest amount of developed land use and barren land. This supports the findings of Stucker and Lyons (2017) that higher amounts of Si concentrations appeared in areas with of artificial surfaces and lower biomass.

A relationship can be seen in N NO_3 concentrations. Higher agricultural areas and green space correlate to higher concentrations of N NO_3 relative to urbanized, developed areas as seen in the concentration from MRW17-08 to MRW17-10 (4122 ppb to 2958 ppb). This also consistent with previous research that found spatial variation of N NO_3 based on differences between green areas and urbanized land use (Stucker and Lyons, 2017; Gardner and Carey, 2004).

The pH was alkaline (basic) throughout the watershed, this most likely reflects the nature of the underlying limestone/dolostone bedrock through the region. It has been shown that concrete, which uses limestone as a major aggregate, increases the pH of water flowing through it by as much as 14% (Sansalone and Buchberger, 1997).

Many of the nutrients and major ions remain relatively stable/uniform throughout the sampled spatial distribution. Essentially all of the cations and anions concentrations remained near the same concentration, or rose in concentrations in relation to increase upstream drainage area. There were no sharp spikes nor deep dips, for the majority of the analytes collected.

CONCLUSIONS

The majority of the major anions and cations remain at relatively unchanged concentrations along the Great Miami River, or only increased alongside upstream drainage area. This leads to the conclusion that there is no major variational factors along the stream. This is supported by the fact that land use type throughout the watershed does not change by a significant amount, changing with standard deviations of less than 0.06 for all land use types, with agricultural (the highest) having a STD of 0.059 and pasture/hay land use type changing with a STD of 0.019 based on percentages of total upstream area that drains into sampled point. There was an apparent link betweem concentrations of N NO_3 dropping as land use type transitions from predominately agricultural surroundings to urbanized near Dayton. A relationship was also observed between higher amounts of Si concentrations near areas of higher amounts of urbanized, man-made surfaces. Decades of data from the Great Miami River watershed for any Cl concentrations show increased levels during winter months, which has been thought to be caused by an increase of salt on the roads in winter months. The pH remained basic along the river, which was expected from the regions covered bedrock of limestone, dolostone, and shale, and that farmers apply basic fertilizer (lime, phosphorus, nitrogen) in this region. In many of the cations and anions, a relationship relating to land use could not be observed. The concentrations stayed relatively consistent along with land use type, so the null hypothesis cannot be rejected.

RECOMMENDATIONS FOR FUTURE WORK

One could expand upon this study by sampling during drought and precipitation events. The samples collected during times of high or low precipitation could be used to calculate a numerical coefficient of the role that water leeching and runoff have on this watershed's streamwater chemistry. Seasonal variations could be measured to gain a spatial distribution to give insight on how streamwater chemistry changes through space and time. The data could be used to help model spatial dissolved nutrient flow. This could also be expanded upon to identify, classify, and model point vs nonpoint sources of stream nutrients. Future studies could be conducted post land use type changes (major urbanization, deforestation, agricultural changes, etc.) and see how much the streamwater chemistry changes based on the percentage of area of land use type change.

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APPENDICES

PO4 Concentrations

Sample #	PO4 ppb run 1	PO4 ppb run 2	PO4 ppb average
MRW-01	8.1	12.6	10.35
MRW-02	29.2	29.3	29.25
MRW-03	31.5	28.8	30.15
MRW-04	43.5	38.9	41.20
MRW-05	55.4	51.7	53.55
MRW-06	48.1	43.4	45.75
MRW-07	63.2	60.5	61.85
MRW-08	57.6	54.3	55.95
MRW-09	55.8	39.3	47.55
MRW-10	59.8	59.5	59.65
MRW-11	73.0	73.0	73.00

NH3 Concentrations

Sample #	NH3 ppb run 1	NH3 ppb run 2	NH3 ppb average
MRW-01	3.4	3.6	3.49
MRW-02	2.2	3.9	3.04
MRW-03	2.7	3.3	3.00
MRW-04	2.4	3.8	3.06
MRW-05	3.0	4.1	3.53
MRW-06	2.8	4.2	3.48
MRW-07	3.2	4.3	3.75
MRW-08	2.7	3.8	3.23
MRW-09	3.3	2.8	3.06
MRW-10	2.4	2.0	2.21
MRW-11	3.8	2.7	3.25

N NO3 Concentrations

Sample #	N NO3 ppb run 1	N NO3 ppb run 2	N NO3 ppb average	Compensation for Dilution N NO3 ppb
MRW-01	374.8	371.3	373	3,730
MRW-02	326.6	330.8	328	3,287
MRW-03	337.9	337.1	337	3,375
MRW-04	387.5	386.7	387	3,871
MRW-05	392.6	391.1	391	3,918
MRW-06	406.8	404.6	405	4,056
MRW-07	416.9	416.4	416	4,166
MRW-08	413.0	411.6	412	4,122
MRW-09	504.8	500.5	502	5,026
MRW-10	278.4	281.6	280	2,800
MRW-11	301.3	290.5	295	2,958

Si Concentrations

Sample #	Si ppb run 1	Si ppb run 2	Si ppb average	Compensation for Dilution Si ppb
MRW-01	214.9	208.4	211.64	2,116
MRW-02	227.9	223.9	225.91	2,259
MRW-03	256.8	252.2	254.54	2,545
MRW-04	276.3	270.7	273.50	2,735
MRW-05	285.5	278.2	281.85	2,818
MRW-06	269.6	264.3	266.92	2,669
MRW-07	275.5	284.3	279.89	2,798
MRW-08	295.0	289.9	292.42	2,924
MRW-09	282.0	274.3	278.15	2,781
MRW-10	317.2	336.7	326.97	3,269
MRW-11	350.1	353.0	351.55	3,515

Anion Concentrations

	F mg/l	Cl mg/l	est. N NO2 mg/l	Br mg/L	NO3 N mg/l	SO4 mg/l	PO4 P mg/l
MRW17-01	0.28	26.0	0.010	0.019	3.80	33.7	0.011
MRW17-01 replica	0.28	26.0	0.011	0.019	3.80	33.6	0.012
MRW17-02	0.29	27.9	0.008	0.019	3.39	37.3	0.028
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MRW17-05	0.28	32.0	0.007	0.022	3.96	39.5	0.051
MRW17-06	0.27	31.1	0.016	0.022	4.05	38.5	0.046
MRW17-07	0.25	31.4	0.010	0.022	3.88	35.7	0.054
MRW17-08	0.26	32.6	0.009	0.024	4.07	35.6	0.048
MRW17-09	0.23	33.8	0.005	0.022	5.25	35.0	0.024
MRW17-10	0.24	42.4	0.011	0.025	2.53	38.2	0.044
MRW17-10 replica	0.24	42.5	0.011	0.026	2.53	38.3	0.042
MRW17-11	0.23	39.2	0.014	0.026	2.68	38.4	0.052

Cation Concentrations

	Li mg/l	Na mg/l	K mg/l	Mg mg/l	Ca mg/l
MRW17-01	0.004	14.08	2.61	29.19	78.36
MRW17-01 replica	0.003	14.24	2.60	29.22	78.63
MRW17-02	0.004	15.94	2.92	28.74	78.95
MRW17-03	0.004	16.39	2.98	28.53	78.92
MRW17-04	0.004	18.07	3.30	28.86	79.34
MRW17-05	0.004	19.68	3.36	28.85	80.19
MRW17-06	0.004	18.56	3.28	28.83	79.60
MRW17-07	0.004	20.55	3.34	28.92	79.95
MRW17-08	0.003	19.63	3.12	29.62	81.64
MRW17-09	0.003	18.51	2.55	33.81	90.93
MRW17-10	0.004	25.08	2.89	36.74	79.37
MRW17-10 replica	0.004	25.08	2.89	36.75	79.73
MRW17-11	0.005	23.00	2.89	36.53	91.77

Sample	Discharge (Cubic feet per second)	Discharge Deviation from historical Average (Cubic feet/second)	Gage Height (feet)
MRW-01 (Site Name: Great Miami River at Sidney OH)	~490	~100	2.175
MRW-04 (Site Name: Great Miami River at Piqua OH)	~600	~50	2.050
MRW-06 (Site Name: Great Miami River at Troy OH)	~450	~50	2.670
MRW-08 (Site Name: Great Miami River at Taylorsville OH)	~1,080	~390	3.700
MRW-09 (Site Name: Stillwater River at Englewood OH)	N/A	N/A	3.690
MRW-10 (Site Name: Great Miami River at Dayton OH)	~2,100	~100	25.650
MRW-11 (Site Name: Mad River near Dayton OH)	~655	~65	3.200

Sample	DCP Battery Voltage (volts)	Drainage Area (miles squared)	Measured pH
MRW-01 (Site Name: Great Miami River at Sidney OH)	13.2	541	7.75
MRW-04 (Site Name: Great Miami River at Piqua OH)	13.5	866	7.67
MRW-06 (Site Name: Great Miami River at Troy OH)	12.6	926	8.05
MRW-08 (Site Name: Great Miami River at Taylorsville OH)	13.5	1,149	7.92
MRW-09 (Site Name: Stillwater River at Englewood OH)	13.3	650	8.19
MRW-10 (Site Name: Great Miami River at Dayton OH)	12.7	2,511	8.02
MRW-11 (Site Name: Mad River near Dayton OH)	13.5	635	7.77

Sample	Latitude and Longitude of Gauge	Actual Latitude and Longitude sampled from
MRW-01 (Site Name: Great Miami River at Sidney OH)	40°17'13" N 84°09'00" W	40°17'17" N 84°09'00" W
MRW-04 (Site Name: Great Miami River at Piqua OH)	40°09'03" N 84°13'44" W	40°09'01" N 84°13'42" W
MRW-06 (Site Name: Great Miami River at Troy OH)	40°02'25" N 84°11'52" W	40°02'26" N 84°11'55" W
MRW-08 (Site Name: Great Miami River at Taylorsville OH)	39°52'28" N 84°09'43" W	39°52'30" N 84°09'43" W
MRW-09 (Site Name: Stillwater River at Englewood OH)	39°52'13" N 84°17'10" W	39°49'59" N 84°15'10" W
MRW-10 (Site Name: Great Miami River at Dayton OH)	39°45'55" N 84°11'51" W	39°45'52" N 84°11'28" W
MRW-11 (Site Name: Mad River near Dayton OH)	39°47'50" N 84°05'19" W	39°47'52" N 84°05'23" W

Sample	sq mi
	Total Drainage Area
MRW-01	577
~MRW-02	
MRW-03	844
~MRW-04	
MRW-05	887
~MRW-06	
MRW-07	1024
~MRW-08	
MRW-10	2509
~MRW-09	697
MRW-11	659

	sq mi	% of area	sq mi	% of area	sq mi	% of area
	Open water		Developed, Open Space		Developed, Low Intensity	
MRW-01	10.34	0.00	37.79	0.00	9.0187	0.00
~MRW-02						
MRW-03	10.78	0.02774	55.34	0.06557	15.89	0.01882
~MRW-04						
MRW-05	13.31	0.015	59.63	0.067	19.007	0.0214
~MRW-06						
MRW-07	14.17	0.0138	70.125	0.06848	25.48	0.02489
~MRW-08						
MRW-10	25.54	0.0101	199.56	0.07954	93.69	0.03734
~MRW-09	2.28	0.0032	48.58	0.0697	19.147	0.027
MRW-11	7.95	0.01206	64.3	0.0975	37.4	0.0567
VAR.p		7.88068E-05		0.000797047		0.000144073
STD		0.008877318		0.028232028		0.012003051
VAR.p WT		6.86072E-05		0.000777191		0.000258756
STD WT		0.008282943		0.027878154		0.016085902

	sq mi	% of area	sq mi	% of area	sq mi	% of area
	Developed, Medium Intensity		Developed, High Intensity		Barren Land	
MRW-01	2.292	0.00	1.078	0.00	0.4703	0.00
~MRW-02						
MRW-03	4.64	0.0055	2.3671	0.0028	0.6359	0.0007535
~MRW-04						
MRW-05	6.298	0.0071	3	0.00338	0.8093	0.000912
~MRW-06						
MRW-07	8.6265	0.00842	3.93	0.003839	0.8265	0.000807
~MRW-08						
MRW-10	31.55	0.0125	14.05	0.0056	1.47	0.0005866
~MRW-09	4.99	0.0071	2.235	0.0032	1908	0.00027377
MRW-11	12.34	0.0187	5.22	0.00792	0.4156	0.00063
VAR.p		1.65114E-05		3.31203E-06		1.02663E-07
STD		0.004063423		0.001819897		0.000320411
VAR.p WT		2.922E-05		5.16792E-06		8.77224E-08
STD WT		0.005405552		0.002273306		0.00029618

	sq mi	% of area	sq mi	% of area	sq mi	% of area
	Deciduous Forest		Evergreen Forest		Mixed Forest	
MRW-01	52.56	0.00	0.3406	0.00	0.01	0.00
~MRW-02						
MRW-03	74.175	0.08788	0.4578	0.00054243	0.025	0.00
~MRW-04						
MRW-05	77.156	0.08698	0.4625	0.0005214	0.028125	0.00
~MRW-06						
MRW-07	83.5	0.0815	0.5109	0.000989	0.03125	0.00
~MRW-08						
MRW-10	212.74	0.08479	1.846	0.000736	0.2218	0.00
~MRW-09	42.7	0.06126	0.303	0.000434	0.0578	0.00
MRW-11	72.989	0.1107	0.925	0.0014	0.0859	0.00
VAR.p		0.001143941		1.04767E-07		6.24523E-10
STD		0.033822202		0.000323678		2.49905E-05
VAR.p WT		0.00105468		1.67652E-07		1.51914E-09
STD WT		0.03247584		0.000409453		3.89762E-05

	sq mi	% of area	sq mi	% of area	sq mi	% of area
	Shrub/Scrub		Grassland/Herbaceous		Pasture/Hay	
MRW-01	0	0	6.36	0.01	39.54	0.069
~MRW-02						
MRW-03	0	0	10.41	0.0123	61.06	0.07234
~MRW-04						
MRW-05	0	0	10.978	0.0123	62.09	0.07
~MRW-06						
MRW-07	0	0	12.98	0.0126	66.55	0.0649
~MRW-08						
MRW-10	0.028125	0.0000112	32.428	0.0129	173.91	0.0693
~MRW-09	0.025	0.00003586	8.9	0.0127	25.14	0.036
MRW-11	0.00156	0.00000237	8.94	0.0135	71.56	0.1086
VAR.p		2.00704E-11		1.43136E-07		5.85706E-06
STD		0.00000448		0.000378333		0.002420136
VAR.p WT		1.52564E-10		2.56114E-07		0.000382873
STD WT		1.23517E-05		0.000506077		0.019567135

	sq mi	% of area	sq mi	% of area	sq mi	% of area
	Cultivated Crops		Woody Wetlands		Emergent Herbaceous Wetlands	
MRW-01	415.967	0.7209	0.05	8.63096E-05	1.7	0.002946
~MRW-02						
MRW-03	604.116	0.71577	0.0609	0.00	2.282	0.0027
~MRW-04						
MRW-05	631.820	0.7123	0.0609	0.00	2.42	0.00272
~MRW-06						
MRW-07	734.310	0.7171	0.0609	0.00	2.64	0.00257
~MRW-08						
MRW-10	1,715.360	0.6836	0.206	0.00	6.28	0.0025
~MRW-09	541.140	0.7764	0.1375	0.00	1.634	0.0023
MRW-11	375.260	0.569	0.0078	0.00	1.51	0.0023
VAR.p		0.000180948		9.14263E-11		2.33994E-08
STD		0.0134517		9.56171E-06		0.000152968
VAR.p WT		0.003484664		2.70581E-09		4.73105E-08
STD WT		0.059031046		5.20174E-05		0.00021751